Team Control Number

# 11135

Problem Chosen

# A

## 2020
**HiMCM**
**Summary Sheet**

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High school is a pivotal point in the lives of millions of teenagers across the nation. High school students learn to be independent and set a path for themselves to follow for the rest of their lives. To develop the skills to cope with the real world, many of them look to find employment. Studies showed that as many as 34.6% of high schoolers pursue job opportunities. However, the decision process for choosing a suitable job is often hard and complicated as there are so many factors to consider. It may be overwhelming for high-school students to decide on their own. To aid students in their search for a suitable job, we have created a Multiple Criteria-Based Job Recommendation Model, which rates available jobs according to the preferences of the student.

Our job recommendation model takes into consideration nine job features: Net Weekly Wage, Flexibility, Hours, Location, Work Environment/Culture, Social Interaction, Physical Activity, Interest and Prerequisites. The first step of our model is to eliminate jobs based on prerequisites and the student' experience. We did so using a Decision Tree to filter out all preferentially invalid jobs. Then, we modified the Analytic Hierarchy Process, commonly used for complex decision making, to fit into our model. Indices for the job feature inputs were calculated and normalized using a Box-Cox Transformation and Min-Max Normalization when necessary. The Analytic Hierarchy Process created a weighted sum of these indices based on the student's preferences. Last, we performed a Cost-Benefit Analysis to create final job indices which we quantitatively sorted by magnitude to rank our job recommendations.

We applied our model in two applications: one to recommend job categories and another to recommend a specific job. Both applications follow similar processes except for different job features and indices calculation. The applications produced job recommendation results for ten fictional persons that were then compared with a simpler tiebreaker ranking method. It became clear that our model was far superior because it was able to account for absolute preferences rather than relative preferences. Furthermore, because our model implemented a weighted sum, it also took into account trade-offs between two factors that the simpler model could not.

Our model is easy to understand and powerful. It is user-friendly and has an intuitive interface in our Job-O-Matic app implementation. In addition, our model is able to account for possible inconsistencies in inputs which makes it very robust. Lastly, our model employs a new way to calculate indices, taking into account a preference range for a job feature using z-scores.

# Contents

# 1 Introduction

As the Pfizer and Moderna COVID-19 vaccines roll out with greater than 90% effective/efficiency rates for both, students are feeling more emboldened to return back to their normal life. For many teens, this means applying for a summer job. We determined which factors high schoolers would consider when applying/looking for jobs, established how these factors and preferences of high schoolers would be used in a model which we created to find/suggest summer jobs, applied the model to realistic situations using the preferences of 10 fictitious people, analyzed the results of said application(s), and created an app in which a person could "use" our model.

While some students already know what their ideal jobs are, most high school students have trouble choosing the right ones for themselves. Evidently, this is by no means a simple decision: there are many factors that need to be considered, not to mention some of these factors may conflict with others. For example, some may want to earn more money but still have concerns with the required physicality of the job. Additionally, most jobs for high schoolers pay higher when they involve interaction with other people. To aid teenagers in evaluating their job choices by creating a model to choose the best one for them based on their preferences and concerns, we developed a Multiple Criteria-Based Job Recommendation system. Our model properly structures a solution for the job matching problem and explicitly evaluates multiple criteria systematically by using Analytic Hierarchy Process (a technique to make decisions with multi-objective optimization). We further constructed two applications of the model for high schoolers: one found the optimal job category from a catalogue of summer jobs after taking into consideration a person's preferences and interest, and another evaluated local summer job listings and chose from available work opportunities a job that was most suitable and beneficial, given certain criteria. It is further possible to combine these two models into a comprehensive version/one by choosing a set of job categories and evaluating the available jobs for the student.

# 2 Assumptions and Factors

## 2.1 Assumptions

**Assumption 1:** A COVID-19 vaccine will be developed successfully by the summer of 2021 and distributed to all citizens in the U.S.
**Justification 1:** Of course, it is very difficult to predict this with certainty. However, as we mentioned before, many drug companies have announced positive initial results for their COVID-19 vaccine. With such a development, we can say that there is at least a decent chance of the pandemic calming down by the summer of 2021 so our high schoolers can take a job outside their house.
**Assumption 2:** High schooler wages are roughly the same as national median wages for entry-level workers in the position.
**Justification 2:** Most high schoolers do not have related work experience. Therefore they will be considered as entry-level workers and be paid at the base wage rate.
**Assumption 3:** High schoolers will only receive job benefits in the form of a wage, so no stock options, health coverage, or retirement plans.
**Justification 3:** We're only considering summer jobs, so students won't be at a company long enough to reap any benefits aside from their daily wage.

**Assumption 4:** High schoolers want to work weekly hours that are within the limits set by the child labor laws of their governing entity.
**Justification 4:** High schoolers looking to apply for a job should be aware of at least some of the basic legislation regarding child labor. The maximum number of hours that they can work per day and per week is arguably the most important bit of information they need to know.
**Assumption 5:** With all other factors being equal, people prefer jobs with higher wages, higher flexibility, lower hours required, and a lower commute time.
**Justification 5:** Under normal circumstances, every high schooler prefers to earn as much money as possible. Further, high schoolers are at the stage in their life when they are turning into independent adults, thus freedom and flexibility is something they want to have more of. Spending less time on a job while earning money faster is always desired. A job that is closer to home will reduce the travel time which is the time spent related to the job. If the hours required for a job should be minimized, so should commute time.
**Assumption 6:** The student's preference with respect to social interactions and physical activity is distributed as a normal curve.
**Justification 6:** Yerkes-Dodson law in psychology states the relationship between arousal (stress) and performance is a bell-shaped curve[1]. Social interaction and physical activity can be considered as stressors as different people have varying tolerable levels of social interaction and physical activity. Thus, a student's preference with respect to social interactions and physical activity is distributed as a normal curve.

## 2.2 Inputs for Job Recommendation Model

There are many factors, i.e., job features, that need to be considered when evaluating high schoolers' summer job options. Our job recommendation model takes into consideration both the data for the job features and user's preference on these features as shown in **Fig. 1.**

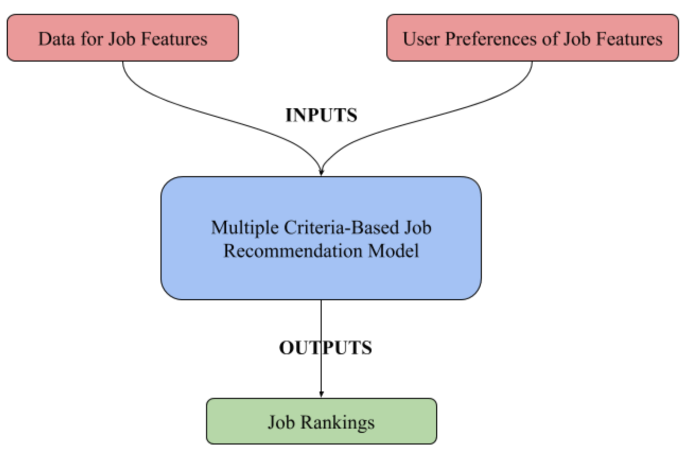



Figure 1: Inputs and Outputs of the Model

Here is the list of the job features that we defined as inputs for our model:

[1]Diamond, David M. "Cognitive, Endocrine and Mechanistic Perspectives on Non-Linear Relationships between Arousal and Brain Function." Nonlinearity in Biology, Toxicology, Medicine, vol. 3, no. 1, 2005, doi:10.2201/nonlin.003.01.001.

- **Net Weekly Wage (WW):** The amount a specific job pays per week minus the expected expenses per week. This takes into account the transportation costs (train tickets, bus tickets, or gas money if the student drives to work) and other work related expenses.
- **Flexibility (F):** Leniency with regards to variation in work hours and when those hours are worked.
- **Hours (H):** The time required to work per week.
- **Location (L):** Where the student works to complete their job. We measured how far away a job is as average commute time to the job in normal traffic. If the job allows the student to work from home, then its commute time is zero.
- **Work Environment/Culture (WE):** The workplace set-up, company culture, and intangible aspects of how the company and the student's potential job function. This is a company-specific feature.
- **Social Interaction (SI):** How often a person would interact with other people, including customers. This is a feature of a job category, not a specific job.
- **Physical Activity (PA):** How much movement and exertion the job requires, on average. This varies from sitting all-day in front of a computer to strenuous manual labor. This is also a feature associated with a job category
- **Interest (I):** The feeling of the student's admiration, curiosity, and engagement for a job at a particular company. This is a company specific feature.
- **Prerequisites (P):** The required skills, certifications, and licenses for a job. These help determine if the student is qualified for certain jobs or not.

Since these job features describe either a general job type or a specific job (or even both), we created two applications for our model to cover the two groups. One application recommends the most suitable job category to a student, and another recommends a specific job to the student to apply for. The specific job features required as inputs for each application are listed below in **Fig. 2:**

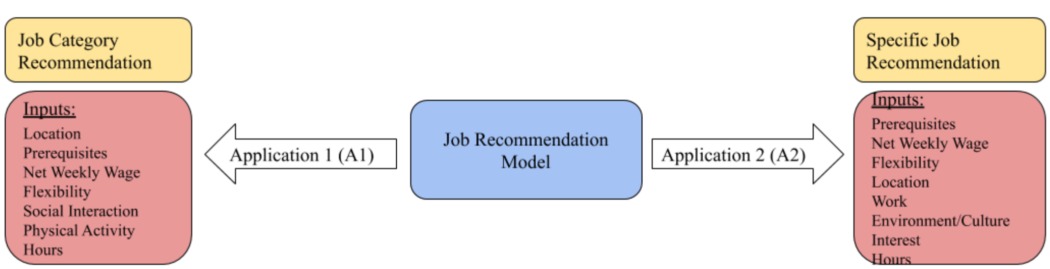



Figure 2: Inputs of the Two Applications

To summarize, our job recommendation model takes inputs including job features and user's preference of the features to create a job ranking using two applications for specific purposes.

# 3 Multiple Criteria - Based Job Recommendation Model

## 3.1 Model Overview

In this section, we develop a Multiple Criteria-Based Job Recommendation system using the job features listed in Section 2.2. Our system, as shown in **Fig. 3**, consists of four steps

1. **Disqualifying invalid jobs:** This process quickly eliminates all jobs that the student does not fulfill the requirements. Filtering out these jobs guarantees that our system will not recommend a job that the student is unable to take based on preference or qualification.

2. **Determine input indices:** This process is to customize priorities of the job features for the student. The priorities for these job features, which we called input indices, depends on the judgments of the pairwise comparison survey result from the student. Naturally, if a student prefers a job with little social interaction, jobs with little to no social interaction would have a bigger index value when compared to jobs with substantial social interaction. Calculations varied depending on application and feature.

3. **Analytic Hierarchy Process:** When making judgments, people are likely to be cardinally inconsistent because they cannot estimate precisely measurement values. If the inconsistencies are intolerable, then we ask the student to reevaluate. After they are corrected, to determine the weights of multiple job features, we applied the well-known Analytic Hierarchy Process (AHP)[2].

4. **Cost Benefit Analysis:** AHP process in step 3 provides a benefit score for each job based on students' preferences. We further take into consideration the cost to each job, which is the hours spent on the job. The cost benefit analysis helps create an objective measure of which job is "worth it" and we use it to make job recommendations.

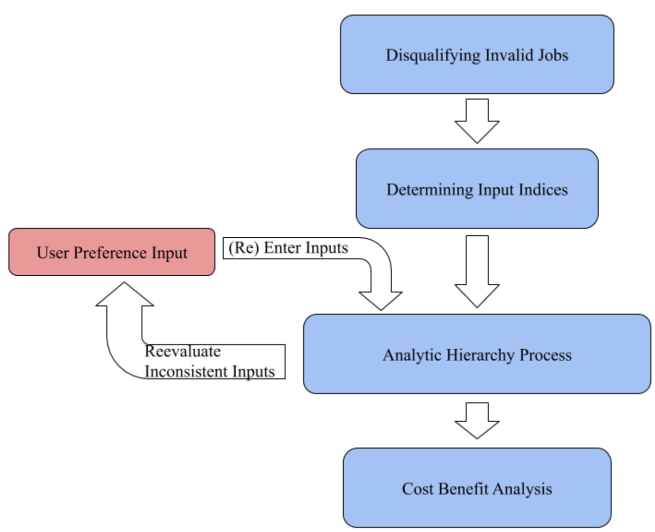



Figure 3: Model Structure

[2]Goepel, Klaus D. (2013). Implementing the Analytic Hierarchy Process as a Standard Method for Multi- Criteria Decision Making In Corporate Enterprises – A New AHP Excel Template with Multiple Inputs, Proceedings of the International Symposium on the Analytic Hierarchy Process 2013, p 1 -10

### 3.1.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was developed in the 1970's by Dr. Thomas Saaty to organize and analyze complex decisions[3]. With multiple factors to be considered, it is very difficult for someone to prioritize these factors. Instead, the AHP takes the student user's preferences to fill out a Pair-Wise Comparison Matrix. To do this, the student will be asked to compare two factors and determine how important a certain factor is to them over the other on a scale of 1 to 9 defined below, where even numbers are intermediate scalings.

| | | **Importance** |
|---|---|---|
| **Scale** | **1** | Equal importance |
| | **3** | Moderate importance |
| | **5** | Strong importance |
| | **7** | Very strong importance |
| | **9** | Extreme importance |

Then, in the matrix, the intersection of row $A$ and column $B$ is how important $A$ is over $B$. If $A$ is less important than $B$, then the reciprocal of the rating of how important $B$ is over $A$ is used. This system gives us the rule that $a_{j,k} = \frac{1}{a_{k,j}}$ in the matrix. The following is an example of a Pair-Wise Comparison Matrix with four factors.

$$A = \begin{bmatrix} 1 & a & b & c \\ \frac{1}{a} & 1 & d & e \\ \frac{1}{b} & \frac{1}{d} & 1 & f \\ \frac{1}{c} & \frac{1}{e} & \frac{1}{f} & 1 \end{bmatrix}$$

The next step of AHP is to normalize the matrix to a Normalized Pair-Wise Matrix. If our Normalized Pair-Wise Matrix is $\overline{A}$, the elements of $\overline{A}$ can be expressed in terms of the elements of the Pair-Wise Comparison Matrix A as

$$\overline{a}_{j,k} = \frac{a_{j,k}}{\sum_{m=1}^{n} a_{m,k}}$$

For example, the value in the intersection of the "Net Weekly Wage" row and "Flexibility" column will be divided by the sum of the entries in the "Flexibility" column. Then, the priorities (weights) of each job feature can be calculated as the average of the values in the rows:

$$p_i = \frac{1}{n} \sum_{m=1}^{n} \overline{a}_{j,m}$$

Now we can calculate the comprehensive score $\omega_i$ for each job. It is the weighted sum of the indices, calculated using the weights generated by AHP:

[3] Goepel, Klaus D. (2013). Implementing the Analytic Hierarchy Process as a Standard Method for Multi- Criteria Decision Making In Corporate Enterprises – A New AHP Excel Template with Multiple Inputs, Proceedings of the International Symposium on the Analytic Hierarchy Process 2013, p 1 -10

$$\omega_i = \sum_{j=1}^{n} p_j \varphi_{i,j}$$

where $\varphi_{i,j}$ is the index of the $j$th factor for the $i$th job.

#### 3.1.1.1 Handling Inconsistent Inputs

At this point when the criteria weights are produced, we want, just for good measure, to check if the produced weights are accurate or not. To do this, we must figure out if the user imputed "rational" preferences. For example, it would be irrational if a student preferred net wage over flexibility, flexibility over physical activity, but physical activity over net wage. A perfectly rational and consistent matrix $A$ could be comprised inputs such that

$$a_{i,j} \times a_{j,k} = a_{i,k}$$

This "rationality" can be measured by the inconsistency of the pairwise comparison matrix using the Consistency Index ($CI$). $CI$ is a function of the maximum eigenvalue $\lambda_{max}$ and the dimensions of the matrix. For an $n \times n$ comparison matrix, $CI$ is defined as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

The lower the value of the $CI$, the more consistent and "rational" the inputs are. We compared the $CI$ to the random index $RI$ which is the average index for randomly generated matrices (0.90 when $n = 4$). The comparison gives us the Consistency Ratio $CR$ that helps us define whether the inputs are consistent or not with a standard 10% threshold.

$$CR = \frac{CI}{RI} < 10\%$$

If the user inputs conflicting data, then we determine the most inconsistent comparison and ask the student to reevaluate his/her decision. To do this, we use our final weights $p_i$ to determine what the comparison should have been. Under consistent circumstances, the comparison $a_{i,j}$ should be equal to the ratio of priorities of the $i$th and $j$th factors. Thus, $a_{i,j}$ in principle *should* be equal to $\frac{p_i}{p_j}$, but this is not the case due to inconsistencies. From this, inconsistency of an input $\varepsilon_{i,j}$ can be measured as $a_{i,j} = \varepsilon_{i,j}\frac{p_i}{p_j}$, so $\varepsilon_{i,j} = a_{i,j}\frac{p_j}{p_i}$. We solve for $\varepsilon$ all inputs and locate the comparison with highest inconsistency and ask the user to try another input.

### 3.1.2 Cost Benefit Analysis

The AHP above created comprehensive scores for each job, which measures the advantages or benefits of a job. However, we must compare the disadvantages or costs of a job: the hours spent. As we took monetary costs into account in the wage index in both our applications of this model, it is only necessary to have to consider the time each job takes up. To do so, we first normalize the number of hours each job requires per week. Since the amount of time a job takes is necessarily a non-negative integer, we can normalize simply by dividing each value by the largest value in the list

$$\overline{h}_i = \frac{h_i}{\max h_i}$$

So the benefit of each job is the comprehensive score, and the cost for each job is the normalized time it requires per week. Using the concept of benefit/cost, this gives us a formula for the final job index:

$$J_i = \frac{w_i}{\overline{h}_i} = \frac{1}{\overline{h}_i}(p_W W_i + p_F F_i + p_S S_i + p_P P_i)$$

which we can use to rank the jobs the student is considering.

## 3.2 Application 1: Job Category Recommendation

Our first application (A1) of our model is to recommend a general type of job for a high schooler based on their preferences. The job features used here are those applicable to all jobs of a particular category, such as location, prerequisites, net weekly wage, flexibility, social interaction, physical activity, and hours.

We start with a list of all possible jobs the average high schooler can get over the summer, and we found data for all the job features of each job based on national averages.

### 3.2.1 Decision Tree to Filter Improper Jobs

Improper jobs are jobs that the student does not fulfill requisites for or does not want to take. We created a decision tree, as shown in Fig. 4 of the procedure in which we filter out all improper jobs. For instance, if a student does not wish to work from home, then all jobs that require employees to work from home will not be recommended to the student. The same is true for the opposite answer to any binary question.

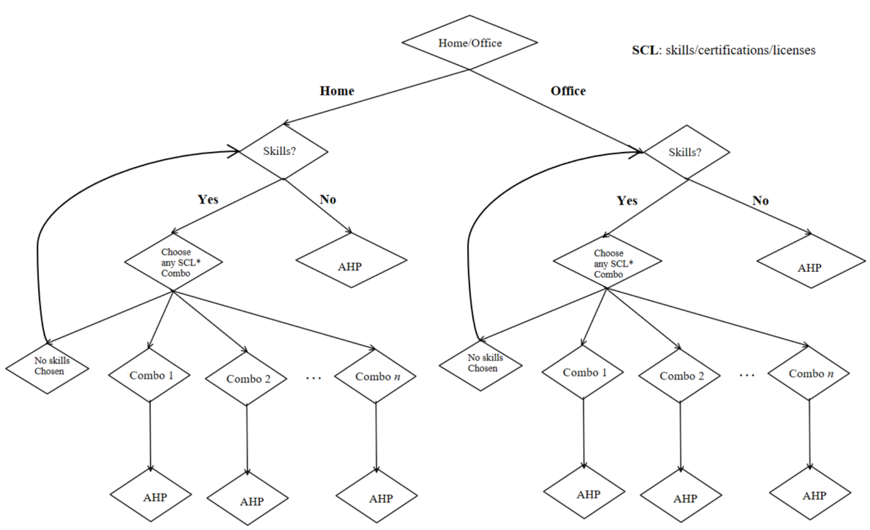



Figure 4: Decision Tree

### 3.2.2 Calculating Input Indices

Now we proceed to the next step of the model where we calculate input indices for net weekly wage, flexibility, social interaction, and physical activity. We noticed that each criterion is measured in different units, for example, hours, dollars. Therefore, they must be normalized to a common numeric range/scale, to allow aggregation into a final score. We choose to use z-score, which indicates the raw score is higher than the mean average, for all indices used in our model. In this way, we can normalize the indices for all job features into numerical and comparable data.

#### 3.2.2.1 Net Weekly Wage

Wage rate is the only quantitative variable that we use in A1. We used wage data taken from varying labor statistics sources on the Internet. More specifically, we gathered the median hourly wages for entry-level workers in the industries we considered, accounting for bonuses like tips for service workers.

Assuming a higher wage rate is always desired, we begin by personalizing the results by allowing the student to enter the minimum wage that they are willing to work for. Jobs with wages lower than this will be removed from further consideration. This step may skew the distribution of the wages of the remaining jobs as shown in Fig. 5 when $11 is set as the minimum wage.

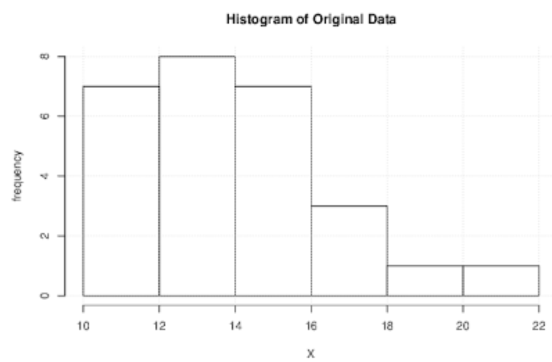
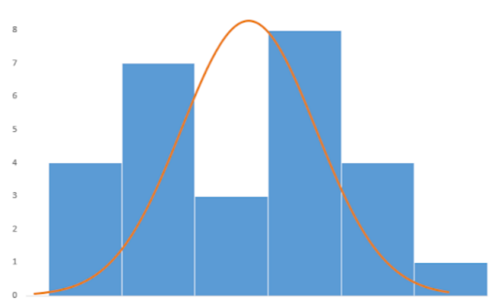



Figure 5: Histogram of Original Data

Therefore, we choose to take a relatively standard approach and apply the Box-Cox transformation to normalize the factor's data. For our example, the resulting distribution is:




This results in a Gaussian distribution in which we can calculate the z-scores for each job's wage rate, and then normalize it using:

$$W_i = \frac{z_i - \min z_i}{\max z_i - \min z_i}$$

#### 3.2.2.2 Flexibility

Flexibility is also a factor which correlates positively with desirability, meaning all students prefer a job that is more flexible. Different from wage rate, there is no direct data to create a reasonable metric. Therefore, we opted for the approach to create a 1 to 9 scale to measure the flexibility:

| | | **Flexibility** |
|---|---|---|
| **Scale** | **1** | Fixed hours (9-5 for example) |
| | **3** | Flex shift |
| | **5** | Flex shift with more flexibility for when the shift is |
| | **7** | Flex schedule (some core hours in office, rest whenever and wherever) |
| | **9** | No set schedule (log your own hours) |

Using this scale, we can rate all the jobs we considered. Similar to wage rate index calculation, the student can input his/her lowest acceptable level of flexibility. Another Box-Cox Transformation is performed, followed by the z-scores calculation and normalization:

$$F_i = \frac{z_i - \min z_i}{\max z_i - \min z_i}$$

#### 3.2.2.3 Social Interaction and Physical Activity

Similar to flexibility, we use the table below to rate the social interaction and physical activity for all jobs.

| | | **Factor** | |
|---|---|---|---|
| | | **Social Interaction** | **Physical Activity** |
| **Scale** | **1** | Entirely individual work | Sitting at a desk all day |
| | **3** | Supervised work | Standing work |
| | **5** | Group work | Walking around |
| | **7** | Basic interaction with customer | Occasional manual labor |
| | **9** | Heavy interaction with customer | Construction work/hard labor |

However, unlike wage rate and flexibility, more social interaction or physical activity are not necessarily more desirable for any student. Instead, every student has their own preference, and thus has an optimal level or range of social interaction and physical activity.

To account for this, we ask the user for the range (on the 1 to 9 scale) that they prefer the social interaction and physical activity to be. We asked for the range as opposed to the singular optimal level in order to account for the student's tolerance of deviations from his/her optimal amount.

The range allows us to create a Gaussian distribution of the desirability for each factor that follows the generic probability density function below:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}^2\right)}$$

The mean of the distribution $\mu$ is the arithmetic mean of the ends of the range produced by the student (since the distribution is symmetrical). The standard deviation of the distribution $\sigma$ an be calculated using the inverse normal distribution function. Taking the range to cover 99% of the Gaussian distribution, the function tells us that $\sigma$ should be 122.576=0.194 times the range.

The z-scores does not represent the user's prefer levels of social interaction and physical activity. Instead, we want to minimize the deviation by minimizing the absolute value of the z-scores: a z-score closer to 0 in absolute value should have an index closer to 1, and a z-score further away in absolute value from 0 should have an index closer to 0. We create the following transformation function on z-scores for both social interaction and physical activity:

$$S_i = \frac{\max|z(s_i)| - |z(s_i)|}{\max|z(s_i)| - \min|z(s_i)|}$$
$$P_i = \frac{\max|z(p_i)| - |z(p_i)|}{\max|z(p_i)| - \min|z(p_i)|}$$

#### 3.2.3 Analytic Hierarchy Process Implementation

With all indices specified for all jobs, we can use AHP to calculate their respective weights. Since location and prerequisites are considered before, this leaves 4 job features for this application: net weekly wage, flexibility, social interaction, and physical activity.

If the student's inputs are inconsistent, we will recommend adjustment for the student to take. Once the desired consistency is reached, we follow the standard to get final comprehensive score for each job (described in the equation below):

$$\omega_i = p_W W_i + p_F F_i + p_S S_i + p_P P_i$$

#### 3.2.4 Cost Benefit Analysis

To calculate the cost benefit, we normalize the hours spent on each job. Then, because the comprehensive scores are the "benefits" and the normalized hours are the "costs," we divide benefits by costs to calculate the final job indices.

### 3.3 Application 2: Specific Job Recommendation

Our first application produces a suggested job category for the student user. It is mainly for students who want to know what type of job most suits them. If they want to know what specific job within a job category is best for them, such as whether to work as a crew member at a local McDonald's or a local Burger King, our second application (A2) can be used. The inputs required for A2 include prerequisites, net weekly wage, flexibility, location, work environment/culture, interest in the job, and of course hours.

Since these are specific jobs, the student is required to input the values of the inputs for each job on top of his/her preferences.

#### 3.3.1 Qualification Verification

The qualification verification in A2 is to make sure the student is prepared for the jobs. This process is quick and simple; of the jobs he/she inputs, the student must check off the jobs he/she is qualified for.

### 3.3.2 Calculating Indices

#### 3.3.2.1 Net Weekly Wage

In A1, we assume the wage rate fits a normal distribution. But since there are limited local jobs in a category, we could not fit normal distribution on these relatively ineffective. Therefore, we opt to use the Min-max normalization, to calculate the wage rate index.

$$W_i = \frac{w_i - \min w_i}{\max w_i - \min w_i}$$

#### 3.3.2.2 Flexibility

Flexibility for a specific job category can be quantified more precisely without worrying about overgeneralizing. The following 3 main factors affect job flexibility:

- time in office
- number of shifts available
- number of workdays per week

It is important to note that when we discuss the number of shifts available, we are referring to shifts that the user can actually take. This is important because child labor laws often restrict minors' working hours to certain times during the day.

It's clearly true that people prefer working at home over working in an office, when only considering flexibility. The same logic applies to the number of possible shifts, and the opposite is true for the number of workdays. With this in mind, we formulate our flexibility score equation:

$$f_i = \left(1 + \frac{\text{work hours out of office}_i}{\text{total work hours}_i}\right)\left(1 + \frac{\#\text{ of shifts}_i}{3}\right)\left(1 + \left(1 - \frac{\#\text{ workdays}_i}{5}\right)\right)$$

We chose to use a multiplicative function rather than an additive one in order to reduce the comparative value of super extreme jobs. In other words, a job that is well-rounded with regards to the flexibility factors will be rated higher than a job that excels in one factor but is poor in the others.

This is based on the observation that for additive and multiplicative functions

$$\forall x, y \in \mathbb{Q}^+ \colon\ x + y = (x) + (y) \qquad \text{(additive)}$$

$$\forall x, y \in \mathbb{Q}^+ \colon\ (1 + x + y) < (1 + x)(1 + y) \qquad \text{(multiplicative)}$$

Note that the addition of a constant to an index has no effect on the result after min-max normalization, which is why we simply used $(x + y)$ in the example above. As a result, when applying a multiplicative scheme, a job that is better in all areas of flexibility will achieve a higher rating than a job that is only exceptional in one area.

As for the choice of the constants in the equation, each one has its own reason. We add 1 to every term in the product in order to prevent any single factor from having too much influence (the most extreme example would be the score dropping to 0 due to one factor). We chose 1 as the addend for simplicity's sake, since the standard 9-5 job can easily be made to have a clean score of 1. Also, since the maximum value of $\left(1 + \frac{\text{work hours out of office}_i}{\text{total work hours}_i}\right)$ is 2, we aim to make the maximum of the other terms also 2 to keep each factor's influence the same.

Now, examine the 5 in the # workdays term. It is a relatively natural choice, since the standard job week has 5 workdays. As having less workdays on a job is better for flexibility, there needs to be an inverse relation between number of workdays and the resulting term, which motivates the decision to use $\left(1 - \frac{\#\ \text{workdays}_i}{5}\right)$. With this choice, a 9-5 job scores a 1 in the category, and the theoretical maximum of the term is 2, consistent with our goals.

It is generally standard for a maximum of 3 shifts per day, which we adopt as the denominator of fraction. This results in a 9-5 job scoring a 1 for this term and the maximum of the term being 2.

The last step is to employ min-max normalization for our final flexibility index

$$F_i = \frac{f_i - \min f_i}{\max f_i - \min f_i}$$

#### 3.3.2.3 Location

For the location index, we only consider the daily commute time as the commute costs has been considered in the wage rate index. Obviously, a smaller commute time is more ideal. Our location index needs to be greater for smaller commute times. So, we used a slightly modified version of min-max scaling:

$$L_i = 1 - \frac{t_i - \min t_i}{\max t_i - \min t_i} = \frac{\max t_i - t_i}{\max t_i - \min t_i}.$$

This formula makes the location index unit-less and range from 0 to 1, thus consistent with our other indices.

#### 3.3.2.4 Work Environment/Culture Index and Interest Index

It is challenging to quantify work environment and culture or interest in a job. There are some commercially available company culture indices, but they're compiled through mass surveys of employees. This data isn't available to an average high schooler. Further, job interest is personal and difficult to quantify. Therefore, we employed another AHP to calculate these indices where student weight their preferences on each pair of jobs for these two factors.

### 3.3.3 Analytic Hierarchy Process Implementation

Similar to A1, now that we have generated input indices, we can use AHP to calculate their respective weights. Since A2 now considers 5 job features, our Pair-Wise Comparison Matrix will be a $5 \times 5$. Following the process described in the model overview, we can calculate the comprehensive score:

$$\omega_i = p_W W_i + p_F F_i + p_L L_i + p_C C_i + p_I I_i$$

### 3.3.4 Cost Benefit Analysis

The process for the cost benefit analysis in A2 is the same as that for A1. We take the comprehensive scores as "benefits" and the normalized hours as "costs." Dividing benefits by costs gives us the final job indices, which are used to rank the jobs.

# 4 Job Search Results for 10 Fictional People

We tested out the two models on 10 fictional people, each of whom has their own set of preferences for the factors. Each fictional person was recommended the top three jobs ranked by each of the two applications of our model.

## 4.1 Biographies of 10 Fictional People

**Arthur(Ar)** is a computer-obsessed geek from ABC High School and loves to spend his time programming and modeling math. He hates talking to other people, despises exercise, and aspires to work at Google one day. He's perfectly fine with a 9 to 5 job as long as it gives him six figures.
**Jacqueline(Jq)** is an athletic girl from DEF High School who gets relatively good grades and is on good terms with everyone at the school. Everyone likes her and vice versa, but she blends in with the crowd. She aspires to play on the US Women's Soccer team, but accepts the possibility of working a normal 9 to 5 job in retail.
**Brody (B)** is an absolute beast when it comes to football and is a five-star recruit from GHI High School. He is basically financially set for life, but his parents want him to get some experience with a "real" job, in case he sustains a career-ending injury in his early years.
**MacKenzie (MK)** is known as the "popular" girl at JKL High School, and everybody wants to "be" her. However, everyone knows that she's actually pretty mean. She comes off as stuck up, and because of her arrogance, her parents decided to make her apply for a job to humble her a bit.
**Hunter (H)** is the nice guy at MNO High School and doesn't appear to have many friends at school. The ones he does hang out with are part of his larger gamer circle, and they incessantly talk about Fortnite and League of Legends at lunch and in the hallways at MNO High School. His parents are finally sick of him sitting in the basement with his PS5 and headset and made him apply for a job.
**Jacob (Jb)** is probably the most antisocial guy you'll find at PQR High School. He always sits in the back corner with his hoodie on and head tilted downwards. Maybe he does want to talk to other people, but his vibe throws everyone off and so no one ever initiates. Worried about his under-socialization, his parents made him go get a job, hoping that he would gain some social skills. He's not looking forward to the social interaction, and he's trying to find a job that will minimize it.
**Olivia (O)** is that girl at STU High School who wears leather pants and jackets and combat boots. She's always talking back to teachers and getting into fights with the lacrosse boys. She's got a tough attitude and her parents were about to send her to military school, but compromised on a job so that she can familiarize herself with real world authority from her supervisors.
**Carl (C)** wanders around VWX High School during his classes. He wears glasses with a permanently food-stained jacket and is always surrounded by his so-called "friends," all of

whom are bad influences. His parents worry every time he goes out, so they want him to get a job to fix his attitude and potentially find better friends.
**Maddie (Md)** is the ever-popular comic at YZA High School who has many friends. She constantly tries to stay on her friends' good side by doing what she does best: cracking jokes. She knows that once she graduates from high school, college will be a chore, and thus is looking for a job to finance her college expeditions.
**Ava (Av)** is a musical theatre fan at BCD High School and sings Defying Gravity in the hallways while skipping away all her troubles. The persistent humming gives her a drama queen, but she's mostly grounded in reality and knows she needs to get a job because Broadway is a long shot.

## 4.2 Personalized Preferences

### Job Category Recommendation Application

| | **WW:F** | **WW:SI** | **WW:PA** | **F:SI** | **F:PA** | **SI:PA** |
|---|---|---|---|---|---|---|
| **Ar** | 3 | 7 | 7 | 3 | 3 | 1 |
| **Jq** | 1 | 1 | 1 | 1 | 1 | 1 |
| **B** | $\frac{1}{5}$ | $\frac{1}{3}$ | $\frac{1}{5}$ | 2 | 2 | 1 |
| **MK** | $\frac{1}{5}$ | $\frac{1}{5}$ | 3 | $\frac{1}{3}$ | 3 | 7 |
| **H** | 3 | 5 | 5 | 3 | 5 | 1 |
| **Jb** | 3 | $\frac{1}{5}$ | 3 | $\frac{1}{7}$ | 3 | 7 |
| **O** | $\frac{1}{5}$ | 5 | 1 | 5 | 3 | $\frac{1}{3}$ |
| **C** | 5 | 5 | 5 | 3 | 3 | 1 |
| **Md** | 4 | $\frac{1}{3}$ | 5 | $\frac{1}{3}$ | 3 | 5 |
| **Av** | $\frac{1}{2}$ | $\frac{1}{7}$ | 2 | $\frac{1}{7}$ | 3 | 7 |

### Specific Job Recommendation Application

| | **WW:F** | **WW:L** | **WW:WE** | **WW:I** | **F:L** | **F:WE** | **F:I** | **L:WE** | **L:I** | **WE:I** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ar** | 5 | 5 | 3 | 3 | 2 | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ |
| **Jq** | 3 | 3 | 1 | 1 | 3 | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ |
| **B** | $\frac{1}{5}$ | 3 | 1 | $\frac{1}{5}$ | 7 | 5 | 2 | $\frac{1}{3}$ | $\frac{1}{5}$ | $\frac{1}{5}$ |
| **MK** | $\frac{1}{5}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | $\frac{1}{3}$ | 3 | 5 | 5 | 3 | 3 | 3 |
| **H** | 3 | 4 | 1 | 3 | 1 | $\frac{1}{3}$ | 1 | $\frac{1}{3}$ | $\frac{1}{3}$ | 3 |
| **Jb** | 3 | 5 | 1 | 3 | 3 | $\frac{1}{3}$ | 1 | $\frac{1}{5}$ | $\frac{1}{3}$ | 3 |
| **O** | $\frac{1}{5}$ | 3 | $\frac{1}{3}$ | $\frac{1}{3}$ | 5 | 3 | 5 | $\frac{1}{5}$ | $\frac{1}{5}$ | 3 |
| **C** | 5 | 3 | 1 | 5 | $\frac{1}{3}$ | $\frac{1}{5}$ | 3 | $\frac{1}{3}$ | 3 | 5 |
| **Md** | 3 | 5 | 5 | 5 | 3 | 1 | 3 | 1 | 1 | 3 |
| **Av** | $\frac{1}{2}$ | 3 | 3 | 1 | 5 | 5 | 5 | 1 | $\frac{1}{3}$ | $\frac{1}{3}$ |

## 4.3 Job Category Results Per Person

Each of the 10 people had their own preferences regarding wage rate, flexibility, social interaction, and physical activity. Additionally, they had varying skill sets, making them eligible to only certain jobs. Using a job pool of 44 jobs that high schoolers could have, we synthesized this information into a job ranking of the top 3 jobs for each of the 10 people.

### 4.3.1 Job Recommendation Results

The following are the top three jobs in order that were recommended to each high schooler:

| AR | JQ | B | MK | H | Jb | O | C | Md | Av |
|---|---|---|---|---|---|---|---|---|---|
| Tutor (1.589) | Catering Coordinator (1.169) | Baby-sitter (1.284) | Tutor (0.715) | Animal Shelter Worker (0.818) | Lawn Care (1.756) | Tutor (0.020) | Catering Coordinator (1.055) | Ice Cream Scooper (1.358) | Golf Course Worker/Caddie (1.850) |
| Lawn Care (0.518) | Animal Shelter Worker (0.748) | House Cleaner (1.257) | | Catering Coordinator (0.782) | House Cleaner (1.423) | | Animal Shelter Worker (1.040) | Gas Station Attendant (1.189) | Tutor (1.598) |
| House Cleaner ((0.513) | Document Archival Services (0.606) | Tutor (1.254) | | Document Archival Services (0.604) | Dog Walker (0.989) | | Ice Cream Scooper (0.917) | Car Wash Attendant (1.112) | Mover (1.315) |

**Preferences for each person:**

| | AR | JQ | B | MK | H | Jb | O | C | Md | Av |
|---|---|---|---|---|---|---|---|---|---|---|
| **MAW** | $14 | $12 | $10 | $16 | $12 | $9 | $15 | $8 | $8 | $12 |
| **MAF** | 3 | 2 | 5 | 6 | 3 | 5 | 6 | 2 | 4 | 3 |
| **SIR** | 1-4 | 3-9 | 4-9 | 3-7 | 3-6 | 1-3 | 1-3 | 4-9 | 5-9 | 5-9 |
| **PAR** | 1-4 | 3-6 | 5-9 | 1-4 | 1-4 | 1-6 | 3-7 | 5-9 | 1-5 | 4-7 |

| | |
|---|---|
| **MAW** = minimum acceptable wage | **SIR** = optimal social interaction range |
| **MAF** = minimum acceptable flexibility | **PAR** = optimal physical activity range |

**Arthur:** looking at the results, tutor appears to have the largest job index by far, and for someone who loves programming and science, this well-paying job seems perfect for him
**Jacqueline:** wanting an office job with limited skills (she lacked communication, teamwork, interpersonal, and organizational skills) combined her restrictive job requirements resulted in a meager recommendation of 4 jobs, though the catering coordinator's job index was reasonably high.
**Brody:** as an unskilled, out-of-office worker who didn't want to spend too much time stuck on the job, our model outputted high flexibility and moderate work hour jobs.
**MacKenzie:** as an out-of-office worker with missing communication, leadership, and interpersonal skills, her ridiculous wage and flexibility requirements of $16 and 6 respectively eliminated all jobs but tutor which only had a job index of 0.715. We recommend that she be less stringent in her requirements/preferences in future uses of our model.
**Hunter:** an office worker that satisfies all basic prerequisites from our pool of jobs, his flexibility and location requirements limited his recommendation list to 4 jobs, but as an avid gamer (and as the job indices reflect), the results seem to fit his presumptive desire for a serene rather than bustling environment.
**Jacob:** a highly qualified and antisocial out-of-office worker, our model produced many results that required only minimal social interaction (e.g. the top three).
**Olivia:** though a highly qualified office worker, her strict wage and flexibility preferences resulted in tutor being the only job recommended with not only an abysmal index, but with an intuitive incongruence as someone with a strong of an attitude as she would not want to patiently work with young children. We recommend that she be less demanding in her preferences.
**Carl:** an unskilled office worker, many possible jobs were rejected, but on account of his leniency in all input features, many of his recommended jobs were still suitable. The jobs

that require teamwork will be a great opportunity for him to make some new friends.
**Maddie:** also an unskilled office worker, her job recommendations also fitted her playful and humorous personality as most involve interaction with customers. Although being an unskilled worker did eliminate some possibilities, we're positive she'll have a great time.
**Ava:** a qualified and bubbly out-of-office worker, her top recommendation of Golf Course Worker/Caddie provides many opportunities for her to socialize while engaging in moderate physical activity. Her energetic personality makes the decently physically taxing job recommendations very suitable as reflected in the indices.

## 4.4 Model Comparison with Simple Job Recommendation Model

Before it became abundantly clear that the consideration of multiple features of jobs was necessary to obtain accurate job recommendations and rankings for student users of our model, we employed a much simpler method to produce some rudimentary results that could later be compared and cross-referenced with our actual model's results.
In this basic model, the user ranks the inputs of the Job Category Recommendation application of our model (wages, flexibility, social interaction, and physical activity) based on importance. The highest ranked input is most important to the user, so this simple model first sorts all jobs based on that input. If jobs are tied for that input, then the next highest ranked input is used as a tiebreaker. This process is repeated until all ties are broken or all inputs are accounted for. However, as we will see, this model is highly inaccurate.
We chose to look at what Ava's job ranking would have been using this simple model compared to what our first application recommended. We first made sure that Ava's preferences were consistent when inputting them into both models. Looking at Ava's Pair-Wise Comparison Matrix, we can see that Ava prioritizes social interaction the most, followed by flexibility, then wage rate, and finally physical activity.
Following this ranking of inputs, we first sorted all jobs by social interaction (which Ava wanted to maximize). Of the top seven jobs as ranked by social interaction, only one had a social interaction score of nine and the rest had a score of eight. Since flexibility was the next most important input, it was used to rank the jobs involved in the six-way tie.
In the end, after all tie-breakers were completed, the final rankings were created as seen below:

| **Simple Model Rankings** | **Our Job Category Model Rankings** |
|---|---|
| Call Center Representative | Golf Course Worker/Caddie |
| Swim Instructor | Tutor |
| Waiter/Waitress | Mover |
| Front Desk Receptionist | Swim Instructor |
| Camp Counselor | Dog Walker |
| Cashier | Delivery Driver |
| Restaurant Host/Hostess | House Cleaner |

A quick inspection reveals that the only overlap between the top seven rankings of the two models/applications was the job of swim instructor which appears as the second highest ranked job in the simple model and the fourth highest ranked job in the Job Category Recommendation application of our model.

Our model is evidently a better model than the simple model because of its receptiveness to changes in preferences, especially marginal ones, of users of our model. Conversely, the simple model accounts for no such change in the preferences, and functions to rank jobs in a sweeping manner based on the most important factor whereby small changes in preferences of the user will not be reflected in the results. Furthermore, the simple model cannot account for the fact that some inputs may be slightly preferred over others, while others can be heavily preferred over others. If Ava were to change her preference for social interaction over flexibility from a great amount to a little amount, the resulting rankings should change to reflect this. Our model completely accounts for this change, but the simple model will be unaffected. Our model takes into consideration the absolute differences in preferences while this simple model only takes into consideration the relative differences. By virtue of our model's sensitivity, precision, and comprehensiveness, the simple model's effectiveness and accuracy in ranking jobs pales in comparison.

## 4.5 Job Specific Ranking Model Results

We implemented our second application for each of the 10 fictional people as well. To run this, we created 5 specific jobs and then let each of the 10 people choose a job from a 3-job subset of the 5 jobs. When listing the jobs, we didn't give them a location or net weekly wage since they depend on each fictional person's own location. Additionally, factors like work environment and culture are purely personalized due to our usage of AHP, so there is no job-specific value for these factors either. With that, the 5 jobs along with their relevant key values, are:

| **Job** | **Work Hours out of Office** | **Total Work Hours** | **Number of Shifts** | **Workdays** |
|---|---|---|---|---|
| CVS Cashier | 0 | 37 | 1 | 5 |
| Math Tutor | 28 | 28 | 2 | 5 |
| Babysitter | 20 | 20 | 0 | 5 |
| McDonald's Prep Cook | 0 | 30 | 2 | 5 |
| Walmart Janitor | 0 | 37 | 0 | 5 |

Since this model is personalized, each job's values are vary slightly for each person. Additionally, for the sake of brevity, each person's jobs are abbreviated as Job 1, Job 2, and Job 3 in future tables. For each fictional person, they are as follows:

| **Job** | **AR** | **JQ** | **B** | **MK** | **H** | **Jb** | **O** | **C** | **Md** | **Av** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Job 1 (J1)** | Walmart Janitor ($500, 30-min) | Walmart Janitor ($490, 30-min) | Walmart Janitor ($495, 25-min) | Walmart Janitor ($505, 15-min) | Walmart Janitor ($510, 20-min) | Walmart Janitor ($1005, 25-min) | CVS Cashier ($485, 30-min) | CVS Cashier ($450, 10-min) | CVS Cashier ($450, 20-min) | McDonald's Prep Cook ($485, 10-min) |
| **Job 2 (J2)** | CVS Cashier ($440, 15-min) | CVS Cashier ($445, 25-min) | CVS Cashier ($445, 30-min) | McDonald's Prep Cook ($475, 30-min) | McDonald's Prep Cook ($490, 15-min) | Math Tutor ($435, 15-min) | McDonald's Prep Cook ($450, 20-min) | McDonald's Prep Cook ($485, 20-min) | Math Tutor ($990, 25-min) | Math Tutor ($990, 30-min) |
| **Job 3 (J3)** | Math Tutor ($1000, 20-min) | McDonald's Prep Cook ($475, 20-min) | Baby-sitter ($455, 15-min) | Math Tutor ($1005, 10-min) | Baby-sitter ($430, 20-min) | Baby-sitter ($510, 10-min) | Math Tutor ($1010, 10-min) | Baby-sitter ($430, 25-min) | Baby-sitter ($455, 15-min) | Baby-sitter ($435, 20-min) |

In this job specific model, we employ AHP again in order to create indices. As a result, we need to have each person's comparison matrices, which are listed here.

| | Work Environment/Culture | | | Interest | | |
|---|---|---|---|---|---|---|
| | J1:J2 | J1:J3 | J2:J3 | J1:J2 | J1:J3 | J2:J3 |
| **Ar** | 1/4 | 1/5 | 1/5 | 1/2 | 1/5 | 1/5 |
| **Jq** | 1/3 | 1/3 | 1 | 1/5 | 1/3 | 3 |
| **MK** | 1/5 | 1/7 | 1/3 | 1/3 | 1/7 | 1/5 |
| **H** | 3 | 3 | 1 | 3 | 1/3 | 1/5 |
| **Jb** | 5 | 5 | 1 | 5 | 3 | 1/3 |
| **O** | 3 | 1/3 | 1/5 | 2 | 1/5 | 1/5 |
| **C** | 1/3 | 1 | 3 | 1 | 1/3 | 1/3 |
| **Md** | 1 | 1/3 | 1/3 | 1/3 | 1/3 | 1 |
| **Av** | 3 | 1/3 | 1/5 | 1/5 | 1/3 | 3 |

## Job Specific Results Per Person

| AR | JQ | B | MK | H | Jb | O | C | Md | Av |
|---|---|---|---|---|---|---|---|---|---|
| Math Tutor (1.293) | CVS Cashier (0.747) | Baby-sitter (1.029) | Math Tutor (1.323) | Walmart Janitor (0.695) | Math Tutor (0.625) | Math Tutor (1.250) | McDonald's Prep Cook (0.936) | Math Tutor (0.956) | Baby-sitter (0.953) |
| CVS Cashier (0.164) | McDonald's Prep Cook (0.690) | CVS Cashier (0.605) | McDonald's Prep Cook (0.478) | McDonald's Prep Cook (0.507) | Walmart Janitor (0.573) | McDonald's Prep Cook (0.288) | CVS Cashier (0.281) | Baby-sitter (0.881) | Math Tutor (0.920) |
| Walmart Janitor (0.048) | Walmart Janitor (0.257) | Walmart Janitor (0.171) | Walmart Janitor (0.176) | Baby-sitter (0.468) | Baby-sitter (0.375) | CVS Cashier (0.108) | Baby-sitter (0.240) | CVS Cashier (0.046) | McDonald's Prep Cook (0.108) |

The first entry in each non-header cell is the net weekly wage for that job, and the second entry is the average commute to the job. Job numbers correspond to the order in which the jobs appear in the table immediately above this one.

**Arthur:** similar to the results from A1, the top recommendation as reflected in the high job index of math tutor perfectly suits his interests in STEM fields.

**Jacqueline:** as an average girl who enjoys socializing with many people at school, it's reasonable that the Walmart janitor index was much worse than that of the other jobs. A CVS cashier, our top recommendation, offers much more opportunities for social interaction.

**Brody:** although most people would think that large, burly guys like Brody wouldn't be fit to handle small kids, babysitting ended up being the best option given his preference for high flexibility and his parents' desire for him to learn how to handle more responsibility.

**MacKenzie:** tutoring, a social and flexible job, gives MacKenzie, the "popular girl," opportunities to both socialize on the job and have enough time for her other friends. Arrogance towards pupils would result in immediate firing, so this job will be a good humbling experience.

**Hunter:** not many would think of avid video gamers as good janitors, but the downtime and alone time offered by the job is suitable for his relatively antisocial (to strangers) personality, though he will still have time to talk to his few gamer friends while productively working.

**Jacob:** it's rather surprising at first that a highly antisocial guy like him would have math tutor as a top recommendation, but the pay, flexibility, and low job "cost" completely overrun that premise. However, his loner desires played out in the ranking of janitor above babysitter.

**Olivia:** her desire for high wage and flexibility and the low commute time resulted in math tutor, unsurprisingly, ending up as her top recommended job. Her interest in the job and her preference for its "work environment" also contributed to this quantitatively excellent recommendation.

**Carl:** our results reflect his main desire to meet new people and make new friends, as his top recommended job of McDonald's prep cook required the most teamwork of the three options and had a significantly higher job index.

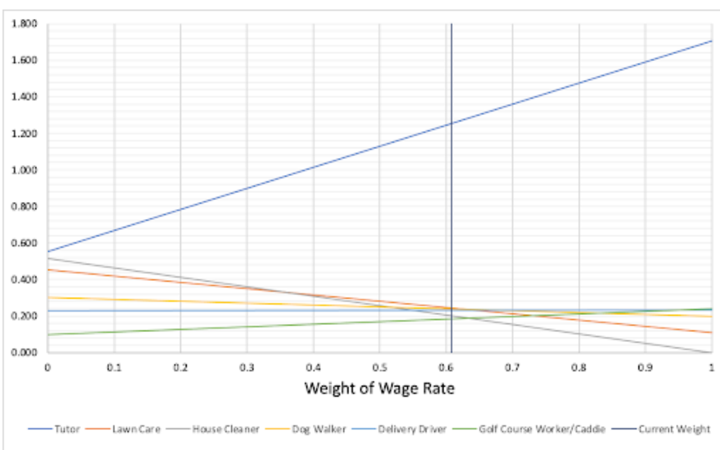
**Maddie:** math tutor, the highest paying job by far, was her top result, and this reflects her main motivation of finding a job that can finance her college life. The social opportunities offered by this job suit her "class clown" personality, making the job more suitable and enjoyable.

**Ava:** being an extremely outgoing girl, our recommendations included two highly social jobs, both with high job indices. Her lack of interest in STEM is outweighed by the high salary offered by being a math tutor, but the social interactions factor allowed babysitter to edge math tutor out.

# 5 Model Analysis

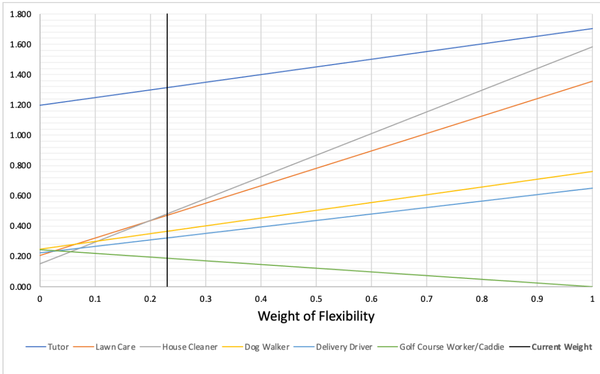
## 5.1 Sensitivity Analysis[4]

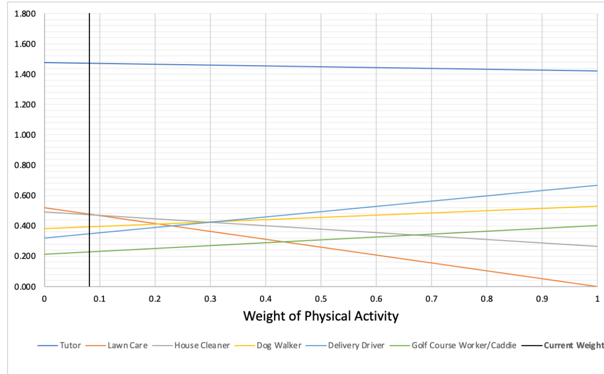
Our result shows that our model can make most suitable suggestions to the student based on the weights of their preferences. We also want to know how sensitive our model is, i.e., the stability of our job recommendation system under changes in the parameters. In particular, we want to know how changing weights of factors can affect final recommendation of jobs and by how much each factor can influence the rankings. To do this, we use our first model for Arthur and alter the weights of each factor while holding all other factors constant. From these results we can find the Absolute-Top (AT) factor, which is the factor that changes the top-ranked job with the smallest change in its weight. We decided to use AT as the most critical factor because we believe that students will pay more attention to the top-ranked job than any other job. Therefore, students will care about the AT the most compared to other factors.



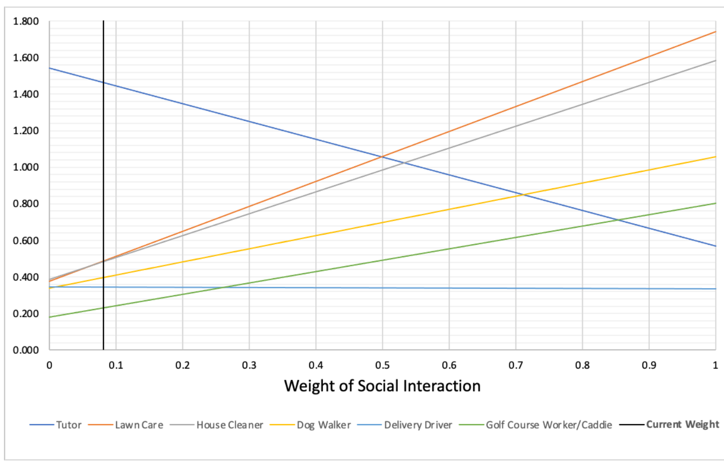

Notice the black vertical line indicates the weight produced from AHP, and its intersection with other lines indicates the final scores for those jobs. Moving the line left or right creates different points of intersections that create different final scores. Looking at the graph, for any weight of wage rate (holding the ratio of other weights constant), tutor will be the job recommended to Arthur because of his preferences. We repeat the same process for flexibility and physical activity and see a similar result:

[4]https://bpmsg.com/sensitivity-analysis-in-ahp/




Again, tutor is recommended to Arthur no matter the weights for the two factors holding the ratio of other weights constant. However, when we perform the analysis for social interaction, our result is more interesting:




At the current weight for social interaction, tutor surpasses all other jobs in the final score and is recommended to Arthur. However, if that weight increases to 0.498, then we see a change in the recommended job: it becomes lawn care. This change means social interaction is the Absolute-Top factor for Arthur, but it requires a substantial change in its weight to change the results.

## 5.2 Strengths

Our models is easy to implement and understand. It is well known that the Analytic Hierarchy Process can be easily implemented for any multiple criteria decision making. The conversion of qualitative variables and factors to quantitative measurements is reasonable and straightforward. Users can easily understand and indicate preferences because they only need to consider two factors. This is much simpler than trying to indicate preferences for all four factors at a time.

Our model provides a safeguard against inconsistent inputs. We calculate the Consistency Ratio (discussed in **3.1.1.1**) to make sure the student's preferences make sense and do not conflict. Otherwise, our system will make suggestions to the student that indicate which input(s) is/are relatively inconsistent. Other models cannot even provide protection from faulty data, less suggest ways to fix it. This makes our model very ***robust***.

Our models include a way to optimize preference of factors that is not used in traditional implementation of the Analytic Hierarchy Process. Conventional use of AHP requires the simple maximization or minimization of factors. Although there were factors in our model that needed to be maximized (wage and flexibility), we also had factors including social interaction and physical activity that needed to be tailored to the student's preference. We analyzed z-scores for this and were able to accurately calculate indices that were not just directly correlated with the levels of social interaction and physical activity. Our models take into account these preferences and are not as naïve as simply maximizing or minimizing factors.

## 5.3 Weaknesses

AHP has an arbitrary 1 to 9 scale that limits input. Firstly, the range is capped off at 9, so if a student believes factor $A$ is 15 times more important than factor $B$, he/she has no way of inputting this extreme preference. Also, the scale makes it somewhat harder for a user to make a decision when comparing two factors that are extremely important to them.

AHP tends to take too long to collect user's response due to the massive amounts of comparisons required. With $n$ factors, there needs to be $\binom{n}{2}$ comparisons between factors. Additionally, depending on its implementation, AHP sometimes also requires comparisons between alternatives (jobs in our models) regarding each factor. For our model, we were able to cut down the number of factors to make the number of comparisons feasible for the user. Additionally, we were able to cut out most of the comparisons between jobs by creating scales to rate each job (described in **3.2.2** and **3.3.2**).

# 6 App Design

We decided that an app would be the best choice to share our model and results with others, as smartphones are already used by 96% of Americans[5], which is comparable with the amount of high schoolers with smartphones, sitting at 95%[6]. Furthermore, since our model needs user input, some of the other methods, like newspapers, are just not practical, which further narrows down the number of possible methods. With the sheer number of people with smartphones being so massive, an app would reach a much larger audience than any of the other methods to share our model, and since the objective of the model is to reach and help as many people as we can, an app is the obvious and best choice to do so.


(a) (b) (c) (d) (e)

[5]https://www.pewresearch.org/internet/fact-sheet/mobile/

[6]https://www.pewresearch.org/internet/2018/05/31/teens-social-media-technology-2018/#:~:text=Some%2095%25%20of%20teens%20now,and%20ethnicities%20and%20socioeconomic%20backgrounds.

The user will first start off with screen (a) with two options, one to choose their ideal summer job industry (Application 1) and another to choose the best summer job in their area (Application 2).

Once the user chooses the application they want to use, they will be taken to screen (b), asking if their ideal job allows them to work at home or office and asking if their job requires skills. This is mostly for the comfort of the user, as some high schoolers do not have any skills, so it is faster for them to just pick that option instead of selecting none for all of the skills. If they choose the option that they have any relevant skills, they will be led to a screen asking them to fill in the skills that they do have and then to screen (c) that asks them to compare how important each of the factors are relative to each other. We did not include the screen containing the questions for a person's skills due to the identical format of that screen and the screen asking for where they want to work. The former screen eliminates the jobs that the person cannot do in the application, and the latter is used to find all of the weights for AHP. If they choose that their job does not require any skills, they will be led directly to screen (c). After both of these steps, our application will run and output the best jobs for the user.

The result of our application will be split between two different screens: screen (d), which lists their ideal jobs and screen (e), which allows them to test out other weights and see what their jobs could have been. The former will list out the ranks of the top three jobs that our application found for the person, including the weights for each of them. It also gives a graphical representation of the weights of each of the factors that they gave. We originally used a table but we realized that it was going to be hard to read, so we changed it to be a graph. The latter part of the results is mostly for the users to try out different weights for each of the variables or who answered the previous questions wrongly. The user can select each of the buttons for each of the different variables and drag the slider to see how the different recommended jobs change. The screen shown above does not show the changed jobs due its size, but in an actual app, the user would be able to scroll down. Overall, our app has a very intuitive interface, since all the user needs to do is answer questions, which is great for high schoolers who are not the most technologically oriented. This allows us to reach the maximum number of people, therefore, sharing our model with the world.

# 7 Conclusion

For both applications of our model, our modified form of AHP was used to determine the weights of inputs (features of specific jobs/job categories). Whereas normal AHP simply maximizes or minimizes its factors (and perhaps incorporates basic feature scaling, dividing all values by the maximum), our version of AHP creates normalized indices that focus on optimization of each of the features of specific jobs/job categories. These normalized indices were created through filtering of preferentially invalid job categories in the first application, transformation by Box-Cox when necessary, and standardization when necessary. They were then multiplied by their respective weights and added together to find total comprehensive scores for each job. These comprehensive scores were then divided by the normalized cost (hours) of each job in a cost-benefit analysis, creating the final job indices. These values were sorted from greatest to least, and the list produced is the rankings (in order of highest to lowest) of our top job recommendations. The results from both applications were analyzed to determine if they were intuitively consistent with the excerpted biographies by comparing descriptions of the characters/students with the rankings suggested and by inspecting the magnitude of the final job indices. Our final determination, as evidenced by the analysis done in our results section, is that our model was both intuitively and quantitatively accurate.

In the future, we would like to apply our model to many actual users who would be able to qualitatively, intuitively, and subjectively assess if the rankings produced by our model were satisfactory and consistent with their preferences. We would further like to make our skills/licenses/certifications list and requirements more comprehensive and more significant in our calculations and generation of rankings. For the convenience of the users of our app, we would also like to find a way to ask less questions while producing equally accurate, if not more accurate, results than our current model's questions would. While these suggestions for future work are both interesting and desirable with regards to implementation, we nonetheless believe that our current model is, once again, remarkably intuitively and quantitatively accurate.

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